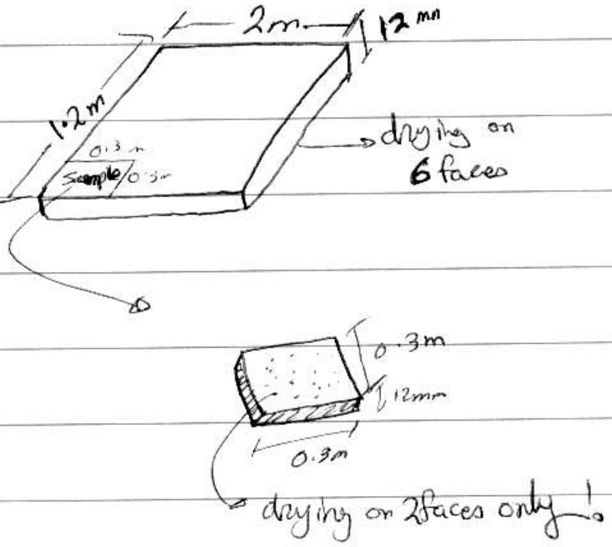
Sec (Revision) Eng. AMR — (Exams). — 21/5/2008

June 2002 : P. 20 4 ©

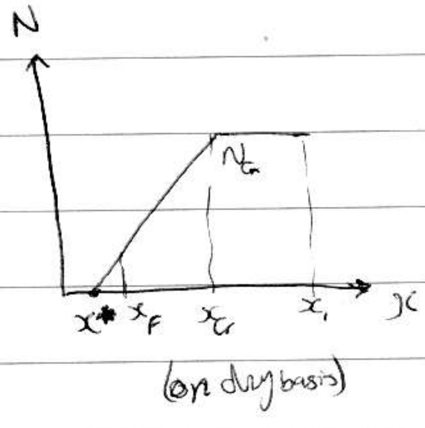


$$x_i = \frac{0.75}{1-0.75} = 3$$

$m_s \frac{\Delta x}{\Delta \theta}$ → $\boxed{1 \times 10^{-4}}$ Kg/sec — not N_{cr}

N_{cr} → Kg/m².sec

$$x_{cr} = \frac{0.6}{1-0.6} = 1.5 \quad @ N_{cr}$$



$$x^* = \frac{0.1}{1-0.1} = 0.111 \quad @ N=0$$

$\therefore m_s = 0.9$ Kg
dry mass

Required: time for drying from 75% → 20% (for the large sheet)

$$x_F = \frac{0.2}{1-0.2} = 0.25$$

$\therefore$ for large sheet.. $m_s \neq 0.9$ Kg

$$N_{cr} = \frac{-m_s}{A} * \frac{dx}{d\theta}$$

$\therefore$ 0.9 Kg → 0.3 × 0.3
? → 2 × 1.2

$\therefore \boxed{m_s = 24 \text{ Kg}}$

$$-N = \frac{-m_s}{A} \frac{dx}{d\theta}$$

→ constant for both small & large sheets

$\therefore \rho = \frac{m}{V} \rightarrow m = \rho V$
$= \rho H A$ — variable

$\therefore \boxed{m \propto A}$

6 faces for large sheet

$$\therefore A = 2\left[2\times1.2 + 1.2\times0.012 + 2\times0.012\right]$$
$$= 4.877\ m^2$$

unit → (1/sec)

$$\therefore N_{Cr} = \frac{-m_s}{A}\frac{\Delta x}{\Delta\theta} = \frac{m_s}{A}\frac{(x_i - x_{cr})}{\Delta\theta}$$

$$\therefore N_{Cr} = \frac{24}{4.877}\times 1.111\times10^{-4}$$

$\therefore 1\times10^{-4}\ Kg/s \div m_{sample}$

$$= \boxed{1.111\times10^{-4}\ 1/sec}$$

$$= 5.47\times10^{-4}\ Kg/m^2.sec$$
$$\simeq \boxed{5.5\times10^{-4}\ Kg/m^2.sec}$$

Note : no hint given for the falling period ∴ assume straight line !

↳ to get equation of falling period : $\boxed{N = mx + b}$

$$@\ x = x_{Cr} = 1.5 \longrightarrow N = N_{Cr} = 5.5\times10^{-4}$$

$$\therefore 5.5\times10^{-4} = m\times1.5 + b \longrightarrow (1)$$

$$@\ x^* = 0.1 \longrightarrow N = 0$$

$$\therefore 0 = m*0.1 + b \longrightarrow (2)$$

from (1) & (2)

$$m = 3.9\times10^{-4}$$
$$b = -3.9\times10^{-5}$$

∴ Const. drying

$$X_{cr}\Big|_{\text{small}} = X_{cr}\Big|_{\text{large}}$$

$$\theta_I = \frac{m_s}{A}\,\frac{X_i - X_{cr}}{N_{cr}} =$$

∴ falling rate drying

$$\theta_{II} = \frac{m_s}{A}\,\frac{(X_1 - X_2)}{(N_1 - N_2)}\,\ln\left(\frac{N_1}{N_2}\right)$$

$$= \frac{m_s}{A}\,\frac{X_{cr} - X_f}{N_{cr} - N_f}\,\ln\left(\frac{N_{cr}}{N_f}\right) =$$

∴ $N_F = m X_F + b = \boxed{5.85 \times 10^{-5}}$ $kg/m^2.s$

OR

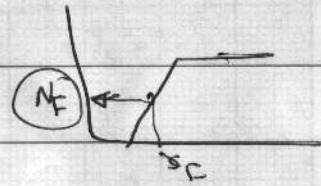
$$\text{Slope} = \frac{N_{cr} - 0}{X_{cr} - X^*} = \checkmark = m$$

$\boxed{N = mX + b}$

so then get b

OR

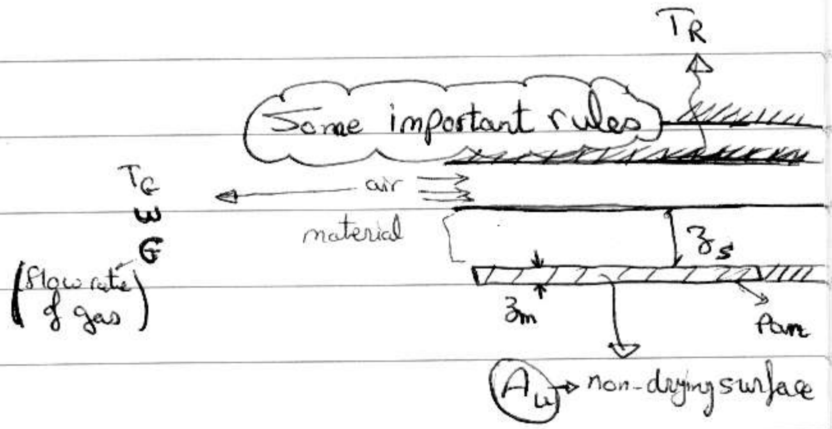
Draw & get N_F from graph



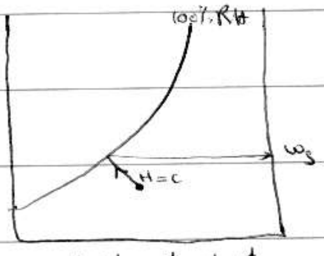
May 2001 :

4-a
P. 17

Some important rules



$N_{Cr} = K_y (\omega_s - \omega)$



psychrometry chart

$\therefore h_g = h_c$

$l_e = 1 = \dfrac{h_g}{C_h K_y}$

↳ get K_y

$G = \dfrac{\dot{m}}{A} = \dfrac{\bar{M}_w \, vP}{RT}$

average molecular weight (air + vapor) ← from psychrometry

q_c = Convection from the G stream
q_K = by conductivity through ~~the~~ solid
q_r = by radiation from hot surface

$q_{total} = N_{Cr} \lambda_s = q_c + q_K + q_r$

λ_s → latent heat of vaporization

detailed!

$q_c = h_c * (T_G - T_s)$

$q_R = h_R (T_R - T_s)$

$h_R = \dfrac{\epsilon (5.729 \times 10^{-8}) (T_R^4 - T_s^4)}{(T_R - T_s)}$

ϵ → emissivity

$q_K = U_K * (T_G - T_s)$

$$\boxed{\frac{1}{U_K} = \frac{1}{h_c} * \left(\frac{A}{A_u}\right) + \frac{Z_m}{K_m}\left(\frac{A}{A_u}\right) + \frac{Z_s}{K_s}\left(\frac{A}{A_m}\right)}$$

K_m → thermal conductivity of pan

K_s → " " of solid

A_m → average area $= \dfrac{A + A_u}{2}$

if

or it will be $A_m = A$ if regular shape

Solution:

givens

$Z_s = 25.4\ mm \times 10^{-3}\ m$

$Z_m = 0.61\ mm \times 10^{-3}\ m$

$K_m = \cancel{13}.3\ W/m.K$

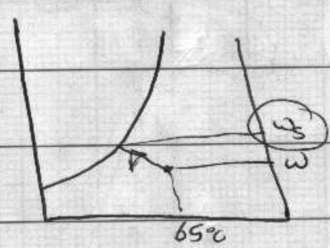
$K_s = 0.865\ W/m.K$

$v_G = 6.1\ m/s$

$T_G = 65 + 273\ K$

$\omega = 0.01$

get ω_s from chart



$T_R = 93.3 + 273\ K$

$\epsilon = 0.92$

$h_c = 0.0204\,(G)^{0.8}$, W/m²K

Find: N_{cr}, T_s

2 trials is enough!

$\because G = \frac{\dot{m}}{A} = \frac{\bar{M}.\ v P}{RT} = \checkmark$

$\therefore h_c = \checkmark$, $\because L_e = 1 = \frac{h_c}{c_s K_y}$

$\hookrightarrow$ get K_y

$\therefore N_{cr} = K_y(\omega_s - \omega) = \checkmark$

Then trial & error $\rightarrow$ to get T_s !!!

only

X, Y, N

$\underbrace{X, Y}_{\frac{A}{A+B}}$, $N \to \frac{S}{A+B}$

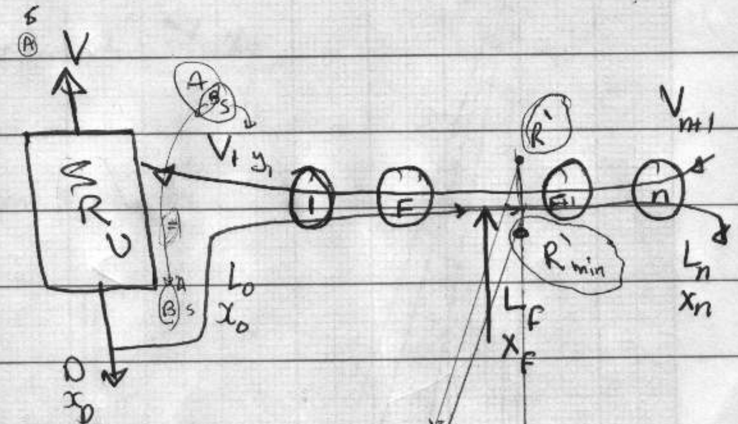
∴ Solvent free basis problem

May 2000 :

P.15

5-b

(MCH) ⟶ A

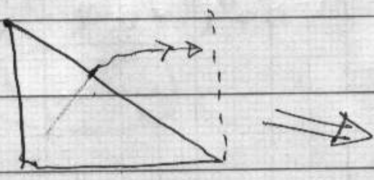


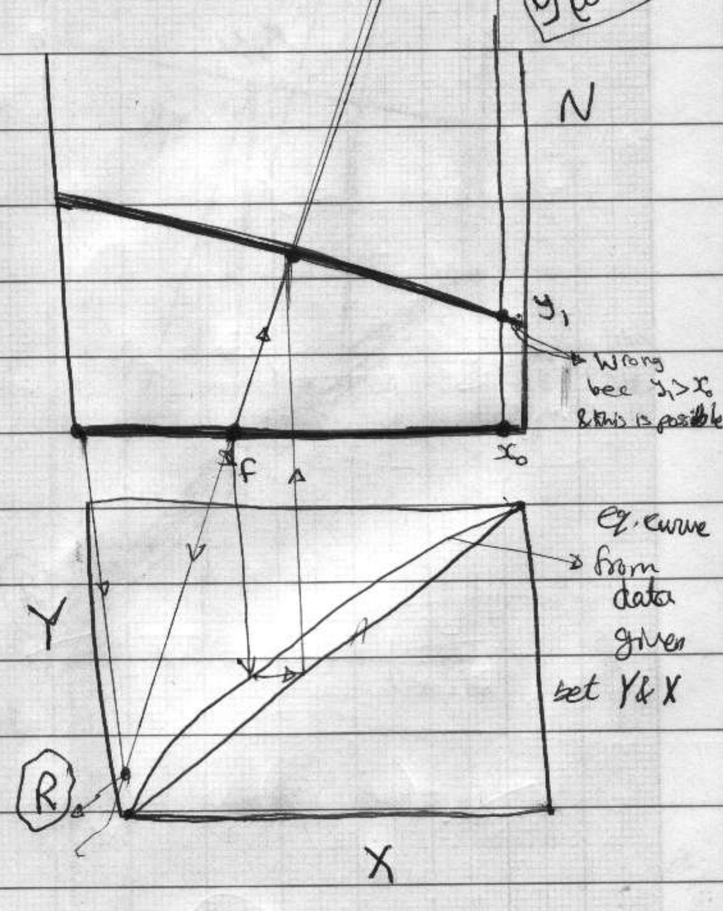
$x_F = 0.4$

$x_n = 0.01$

$x_D = x_0 = 0.98$

$r = 7.7$





1

∴ r_{min}

$$\frac{R' x_0}{R' y_1} = \frac{r+1}{r} \left(\frac{y x_0}{y y_1} \right) \to \infty$$

$$\frac{R'_{min} x_0}{R'_{min} Y_1} = \frac{r_m + 1}{r_{min}}$$

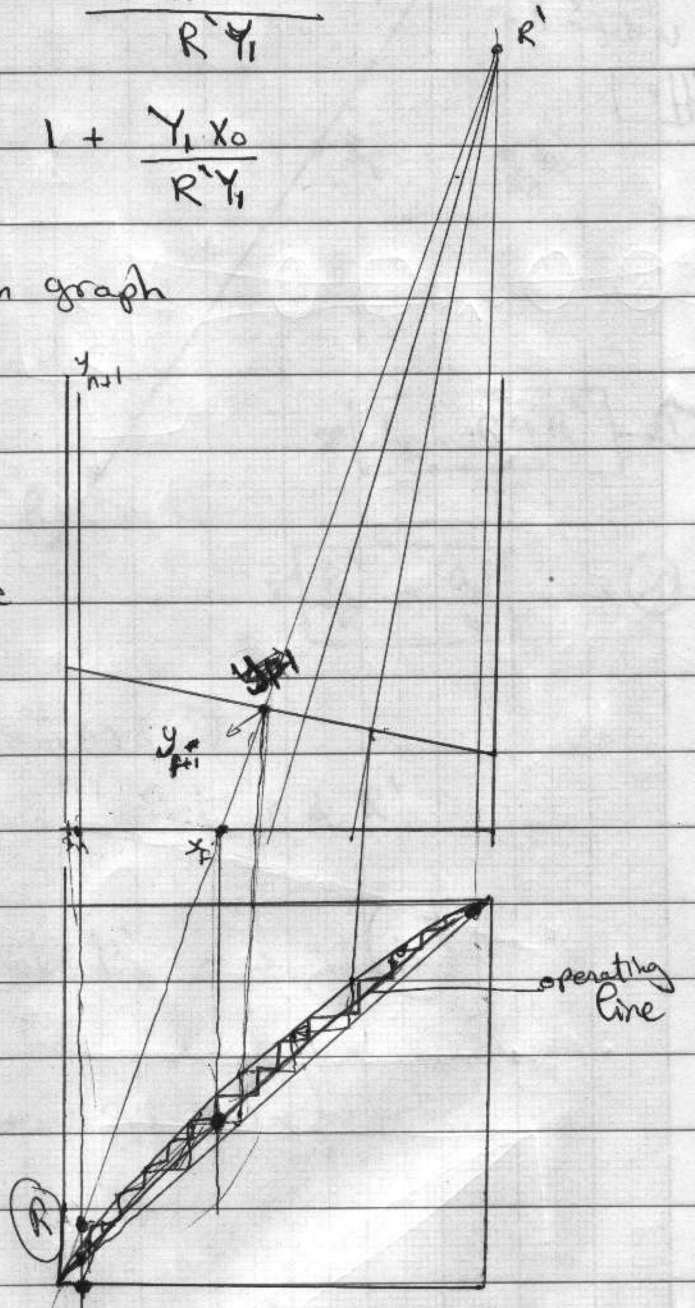
get r_{min}

(2). $L_f = 100\ Kg \Rightarrow NTS$

$$\because \frac{R'X_0}{R'Y_1} = \frac{\overset{7.7}{r+1}}{r} = \frac{R'Y_1 + Y_1X_0}{R'Y_1}$$

$$= 1 + \frac{Y_1X_0}{R'Y_1}$$

$\overline{R'Y_1} = \checkmark$ get R' on graph



↳ data get from solvent free coordinate are $L'_0, V'_1, V', L'_n, V_{n+1}$

$\boxed{L_f = L'_f}$

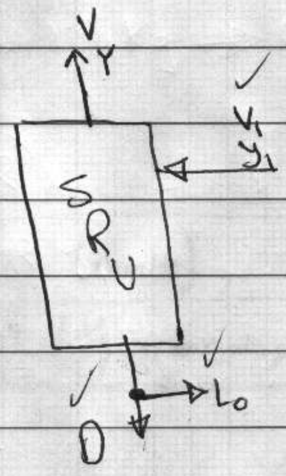
↳ to get original:

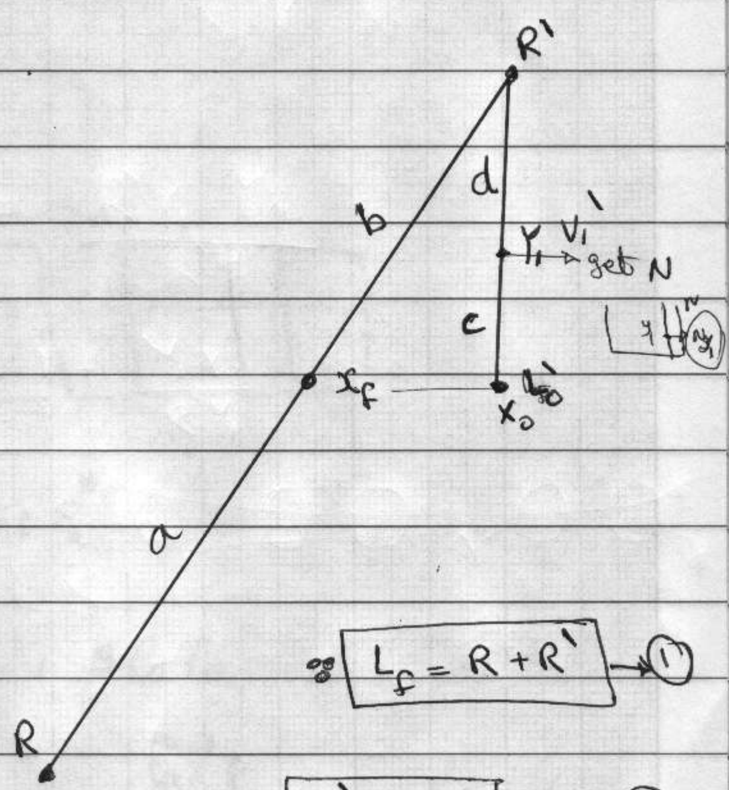
$L_0 = L'_0 (N_{x_0} + 1)$

$\because N_{x_0} = 0 \therefore L_0 = L_0'$

$V_1 = V_1' (N_{y_1} + 1)$

(solvent removed = V) required





∴ $\boxed{L_f = R + R'}$ → 1

∴ $\boxed{\frac{R'}{R} = \frac{a}{b}}$ → 2

∴ from 1 & 2

get R & R'

∴ $\frac{R'}{L'_o} = \frac{c}{d} \Longrightarrow$ get $L'_o \rightsquigarrow$ get L_o

∴ $r = \frac{L_o}{D} \Longrightarrow$ get $D = \frac{L_o}{r} = ✓$

∴ $V_1' = L_o' + R' = ✓$

↳ get $V_1 = V_1'(N_{y_1} + 1)$

∴ $\boxed{V_1 = V + D + L_o}$

May 2007

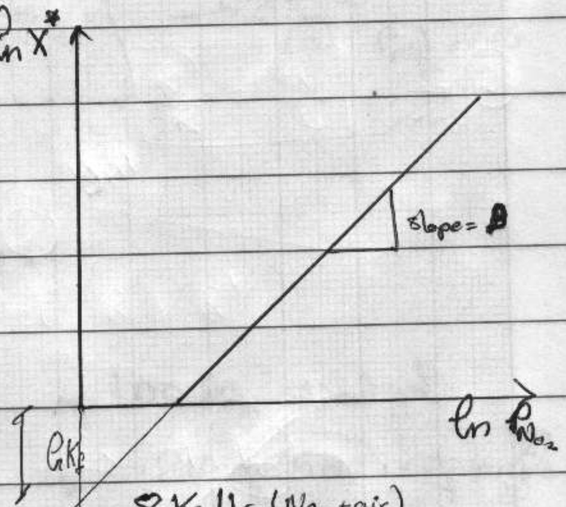
4-b:

P_{NO_2} (mmHg)					
x^* (Kg NO_2/100 Kg silica gel)					

(a) $$x^* = K_f \, P_{NO_2}^{\beta}$$

$$\ln x^* = \ln K_f + \beta \ln P_{NO_2}$$

$$\therefore \boxed{X^* = K_f \, P_{NO_2}^{\beta}} \checkmark$$



(b)

$D = 0.1\,m$, $H = 1\,m$

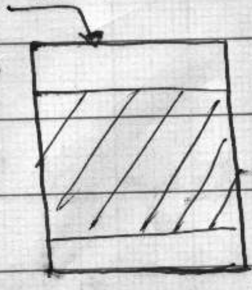
$\rho_b = 0.75\ Kg/L = 750\ Kg/m^3$

8 Kg/hr (NO_2 + air)

1% NO_2

$P_t = 1\,atm = 760\,mmHg$

$T = 298\,K$



ideal: MTZ = 0 & $\boxed{t_B = t_S = t}$

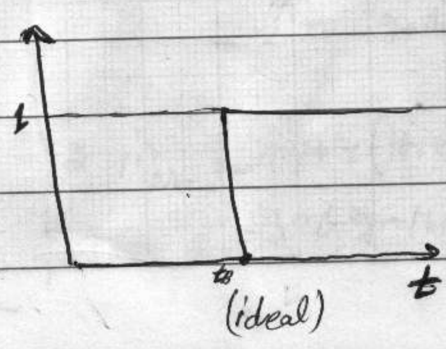
تجهيزات أساسية! →

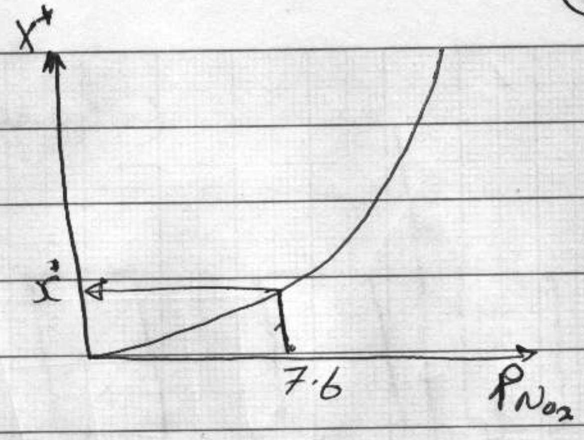
$\ast\ PV = n_T RT$

$\bar{M}_w = 0.01\, M_{w_{NO_2}} + 0.99\, M_{w_{air}}$

$= \checkmark \quad 29.3$

$\therefore \dot{n}_T = \dfrac{8\ Kg/hr}{\bar{M}_w} = \checkmark \ \boxed{0.273}$ Kmole/hr





$\therefore P_{NO_2})_{in} = \frac{1}{100} P_T$

$= \frac{1}{100} \times 760$

$= 7.6$ mmHg

from chart get x^* $\left(\frac{Kg\ NO_2}{100 kg\ silica\ gel}\right)$

or get from

$\boxed{x^* = K_p\, P_{NO_2}^{\beta}}$ $\longrightarrow$ get x^* @ $P_{NO_2})_{in} = 7.6$

$x^* \cong 2.2$ Kg NO_2/100kg si...

$\therefore$ 2.2 Kg NO_2 $\longrightarrow$ 100 Kg silical gel

$m_{NO_2})_{ads.}$ $\longrightarrow$ $\rho V = 750 \times 1 \times \frac{\pi}{4} (0.1)^2 =$ 5.89 Kg

$\boxed{m_{NO_2})_{ads} = 0.13\ Kg_{NO_2}}$

not ideal
get $m_{NO_2})_{ads}$ → @ t_B (0.01) — 0.1
≅ the Same

$m)_{NO_2)\,ads} = t_B \times \dot{m}_{NO_2})_{ads.}$

$\therefore t_B = \frac{0.13 \times 1000}{126} = 1.03$ hr

$= \boxed{62\ min}$

$\therefore \dot{n}_T \approx 274$ gmole/hr

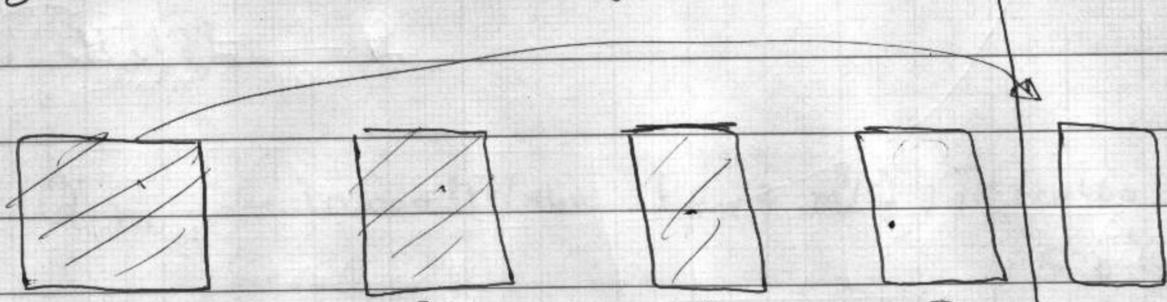
$\therefore n_{NO_2} = \frac{1}{100} \times 274$

$= 2.74$ gmole/hr

$\therefore \dot{m}_{NO_2} = 2.74 \times [14 + 2 \times 16]$

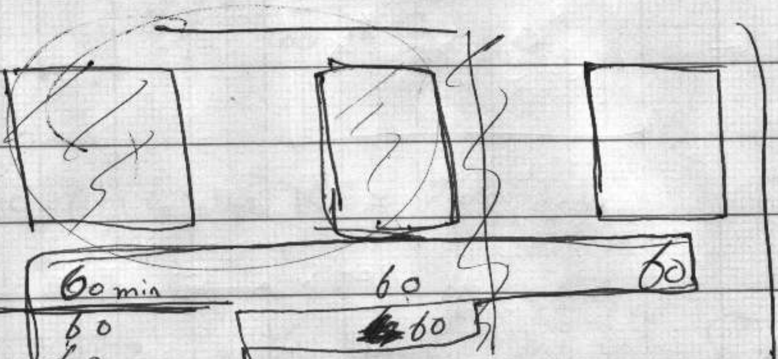
$= 126$ gm/hr

c). ∵ 1.5 hr (regeneration)



example 30min 30min 30. 30

Regeneration { 30min 30 min 30
30min 30
30 min



used. 60 min 60 60

Regeneration { 60 60
60

∴ no. of beds = $\boxed{3}$

May 2006

1. H_{ads} ?

$Q_{inlet_{air}} = 10,000\ ft^3/min\ \ (4.72\ m^3/s)\ ,\ T = 60+460$
$= 520\ ^\circ R$

$P = 14.7\ psi$

$\boxed{R = 10.73}$

$n \rightarrow lb\,mole$

$\rho_B = 36\ lb/ft^3$

working $q = \frac{28\ lb(TCE)}{100\ lb\ carbon}$

x^*

$\therefore\ 2000\ ppm = $ inlet TCE $= \frac{2000\ mole}{10^6\ mole\ feed}$ Gas

$\therefore\ 2000 \times 10^{-6}\ \frac{lbmole\ TCE}{lbmole\ feed}$

if liquid
$ppm = \frac{mg}{lit}$

$\therefore\ P\dot{V} = nRT$

$14.7 * 10000 = n_T \times 10.73 \times 520$

$\therefore\ n_T = \cancel{26} \; 26.4\ lbmole$

$n_{(TCE)} = n_T \times 2000 \times 10^{-6} = 0.0526\ lbmol/min$

$\therefore\ \dot{m}\,(TCE) = 0.0526 \times 131.5 = 6.93\ lb/min$

$t_b = 4\,hr$ $\dot{m}\,[TCE]\big|_{abs} = 6.9 \times 0.995 = 6.89\ lb/min$

$\therefore$ $\text{ads}/_{\text{min}} \times \text{time (min)} = \text{total adsorbed}$

$\therefore$ $6.89 \times 4 \times 60 = \boxed{1654.6 \text{ lb}}$

$\therefore$ 28 TCE $\longrightarrow$ 100 lb carbon

1654.6 $\longrightarrow$?

$m_{\text{Carbon}} = 5909.4$ lb

$\therefore$ $m = \rho V$

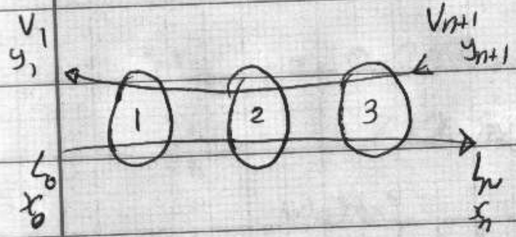
$\therefore$ $V = \dfrac{5909.4}{36} = 164.15 \text{ ft}^3$

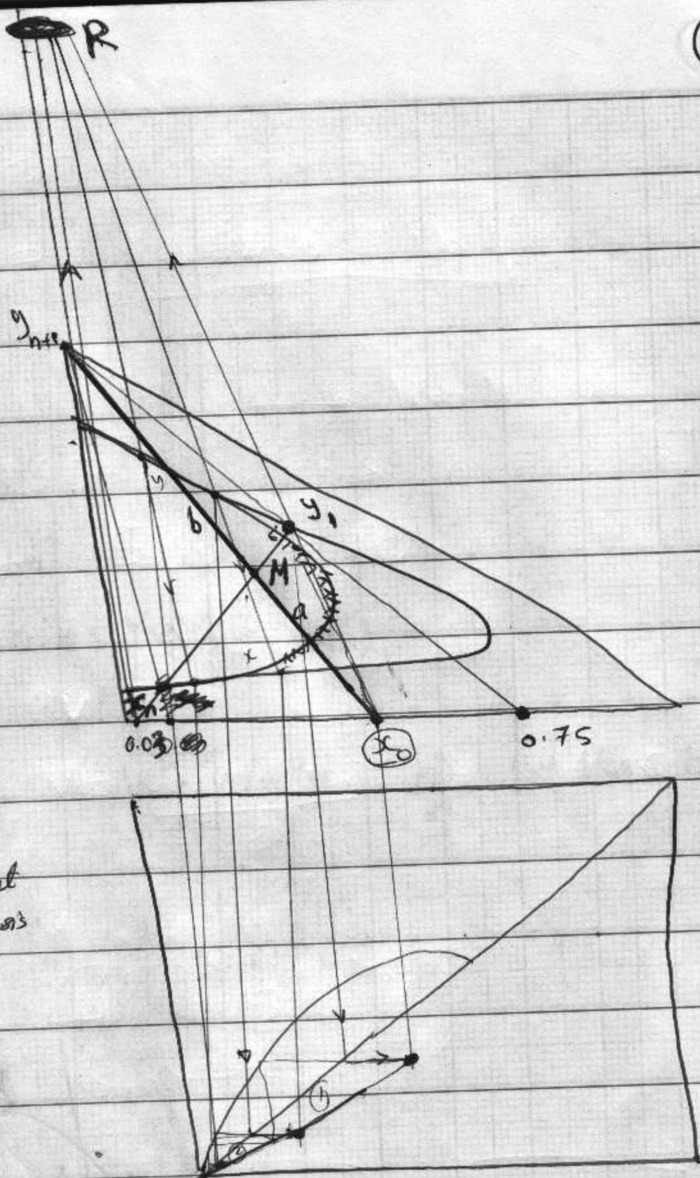
$\therefore$ $V = H_{ad} \times \frac{\pi}{4} d^2$

$\therefore$ $H_{ads} = 5.8 \text{ ft}$

May 2004:

2.





$y_{n+1} = 0$

$y_1 \;, \cancel{x_n} = 0.75$) on solvent free basis
$x_n = 0.03$

required

x_0 for A, B, ~~C~~ ?

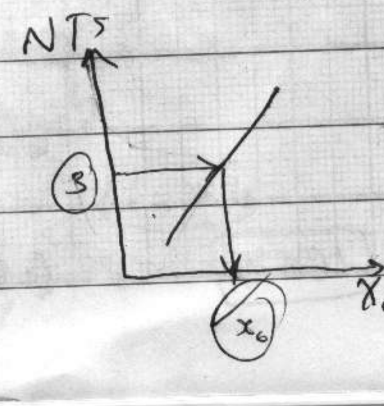
$\frac{V_{n+1}}{L_0}$?

Steps: 1- assume x_0

2- $\overline{x_0 y_1} \cap \overline{x_n y_{n+1}} = R$
(intersect)

3- get NTS

4- trials ⟶ ///



$\therefore \frac{V_{n+1}}{L_0} = \frac{a}{b}$

May 2006 :

p. 31
4

$T = 28.3\,^{\circ}C$

$H_{total} = 0.268\ m$

$\rho_b = 712.8\ Kg/m^3$

$water)_{initial} = 0.01\ Kg\,w / Kg\ solid$

$4052\ Kg/m^2 h$ = mass velocity = $\frac{\dot{m}}{A}$ (of the nitrogen)

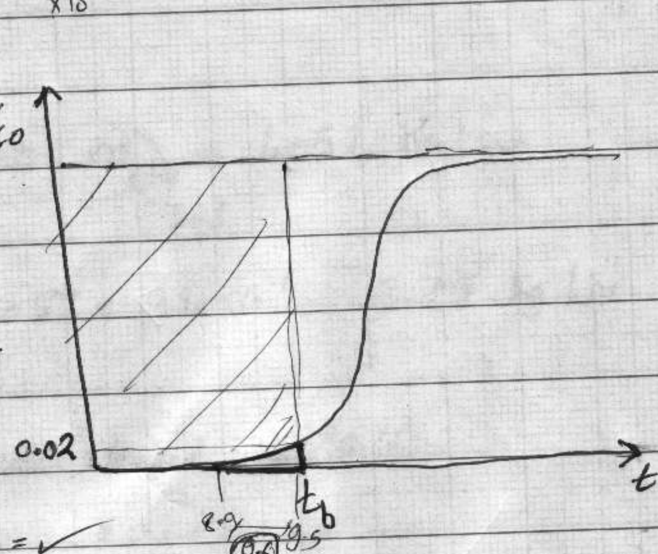
$C_0 = 926 \times 10^{-6}$ Kg water / Kg nitrogen

t					—
C					—
C/C_0	✓	✓	✓		—
~~$\times 10^{-4}$~~	$<6.48 \times 10^{-4}$	6.48×10^{-4}	2.8×10^{-3}		—

t_b (from graph) $\simeq$ ✓ 9.5 hr

fraction total capacity = $\frac{H_u}{H_t} = \frac{t_u}{t_T}$

0.268



$t_u = \square - \Delta =$ ✓

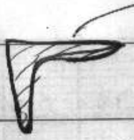
(from last section!)

$\boxed{t_u \simeq t_b}$

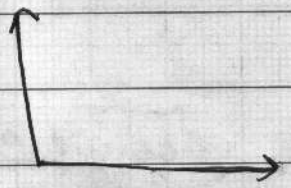
$t_u = (1 \times 9.5) - (\frac{1}{2} \times 0.02 \times 0.6) =$ ✓ $\boxed{9.49\ hr}$

$$\int_0^{\infty} (1 - C/C_0)\, dt$$

$f(t) = (1 - C/C_0)$

$t_t = t_u +$ 

$= 9.49 + \frac{\Delta t}{2} \left[f_0 + f_n + 2[f_1 + f_2 \cdots f_{n-1}] \right]$



$=$ ≡

t	C/C_0	$f(t)$
–		–
–		–
–		–

$H_{\text{unused bed}} = H_T - H_u = H_T \left[1 - \frac{t_u}{t_t} \right]$

$=$ ✓

→ saturation loading capacity of solid

↳ $q = ? \ \frac{Kg_W}{Kg_S}$

قدّيه ماء مصّوا
adsorbtion

$\therefore m_{ads})_{total} = t_{B} * (\dot{m}_{ads})_{\text{inlet flow}}$

$\therefore \ C/C_0 = 0.02$

basis: $1\,m^2$ Area of bed $\therefore \dot{m}_{N_2})_{total} = 4052$ Kg/hr

$m_{ads\ water})_{inlet} = 4052 * 926 \times 10^{-6} = 3.75$ Kg/hr

$\therefore \ C/C_0 = 0.02 \ \therefore$ water adsorbed ≅ 99.98 %

$\therefore \ C_f = 0.02 * C_0$

$\therefore \ C_{ads} = C_0 - C_f$

$$C_{ads.} = 0.98\, C_0$$

$$\dot{m}_{w}\Big)_{ads}\Big|_{inlet} = 0.98 \times 3.75 = 3.675 \ Kg/hr$$

$$\therefore m_{ads}\Big)_{total} = \overset{9.5}{t_B} * 3.675 = \boxed{34.9 \ Kg \ water}$$

$$m_{solid} = \rho V \quad \overset{\text{area assumed}}{}$$
$$= 712.8 \times \hat{1} \times \underbrace{H_T}_{0.268} = 191.03 \ Kg$$

$$m_{\omega}\Big)_{initial} = 0.01 \times 191.03 = 1.9103 \ Kg$$

$$\therefore q = \frac{34.9 + 1.91}{191.03} = 0.193 \ \frac{Kg_w}{Kg_s}$$

---

b $\therefore q^* = 0.193 \frac{Kg_w}{Kg_s}$ (doesn't change). $= \frac{Kg_{w_{ads}} + 0.01 Kg_s}{Kg_s}$

$$\therefore m_{w_{ads}}\Big)_{total} = t_b \ \overset{3.675}{\cancel{m_{ads}}}\Big)_{\substack{inlet \\ flow}}$$

$$\therefore M_{solid} = \rho V = 712.8 \times 1 \times 0.4 = 285.12 \ Kg$$

$$\therefore 0.193 = \frac{Kg_{w_{ads}} + 0.01 \times 285.12}{285.12} \Rightarrow \therefore Kg_{w}\Big)_{ads} = 52.18 \ Kg$$

$$\therefore 52.17 = t_b \times 3.6 \longrightarrow \boxed{t_B = 14.2 \ hr}$$

$$\frac{H_u}{H_t} = \frac{t_u}{t_t}$$

$$\boxed{H_{uNB}} = H_t\left(1 - \frac{t_u}{t_t}\right) = \checkmark$$

Const

↳ get $\frac{t_u}{t_t} \Rightarrow \left(\frac{H_u}{H_t}\right)$ new

$H_{unused} \rightarrow$ عبر عن MTZ

MTZ don't change by height but affected by

- particle size
-
-
-

(not height)

Solve (May 2004) no. 4

May 2001 :

3 .

Some important rules :

1) Batch mode ! لا تخرجوا عن التكامل

$$-\frac{dc}{dt} = K_L\, a\,(C_f - C^*)$$

C_f → of bulk; C^* → equilibrium

نستخدم هذه القوانين
إذا ذكر كلمة mode أو K_L
?!

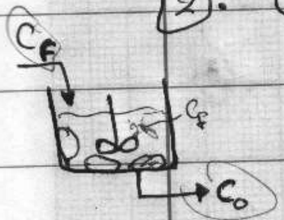
K_L = the external liq. phase M.T coeff.

a = Ext. surface area of the adsorbent / unit vol. of liq.

$$a = \frac{a_{P_s} * S_s}{V_L}$$

a_{P_s}: $\left(\frac{m^2}{kg_s}\right)$; V_L — volume of liquid

2) Continuous mode :



$$\frac{C_{feed} - C_{out}}{t_{residence}} = K_L\, a\,(C_f - C^*)$$

C_f: (C_o) feed; C_f or C_{out}; original; C^* C_f

from bulk liquid to the surface of catalyst

3) SemiCont. mode :

$$S_s \frac{dq}{dt} = K_L\, a\,(C_f - C^*)\, t_{res.} * \dot{V}_L$$

C_f → or (C_{out})
→ if $C_{out} = C^*$
∴ put $C_f = C_f$
not C_{out}

Givens:

$$\dot{C}_f = 3.3\ \frac{mg}{lit},\quad C_{out} = 0.1\ \frac{mg}{lit}$$

$$\frac{S_s}{V_L} = 5\ \frac{gm}{lit.\ solution},\quad K_L = 5 * 10^{-5}$$

$$a_{p_s} = 5\ m^2/Kg$$

a). if $\frac{S_s}{V_L} = 10\ \frac{gm}{lit.\ solution}$

$\boxed{\text{Cont. mode:}}$ $\therefore \frac{C_{feed} - C_{out}}{t_{res}} = K_L\, a\, (C_f - \underbrace{C^*}_{C_{out}})$

$$\therefore a = \frac{a_{p_s} S_s}{V_L} = 5 \times 10 = 50$$

$\hookrightarrow$ get t_{res} //

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b). $\boxed{\text{Semi-cont. mode}}$:

$S_s = 100\ Kg$, $a = \frac{a_{p_s} S_s}{V_L}$, $t'_{res} = 1.5\ t_{res}$.

$\dot{V}_L = 10\ m^3/hr$

$C_i = 0$ $\rightarrow$ ①

$$q = 67\, C^*$$

$$\boxed{S_s \frac{dq}{dt} = K_L\, a\, (C_f - \underbrace{C^*}_{C_{out}})\, t_{res}\, \dot{V}_L}$$

$$\hookrightarrow dq = 67\, dC^*$$

$$\therefore S_s\, 67 \int \frac{dC^*}{C_f - C^*} = \int_0^t dt\ K_L\, a\, t_{res}\, \dot{V}_L$$

get t ✓